

REMARKS

In view of the above amendments and following remarks, reconsideration and further examination are requested.

The specification and abstract have been reviewed and revised to make editorial changes thereto and generally improve the form thereof, and a substitute specification and abstract are provided. No new matter has been added by the substitute specification and abstract. Also, enclosed is a "marked-up" copy of the original specification and abstract to show changes that have been incorporated into the substitute specification and abstract. The attached pages are captioned **"Version With Markings To Show Changes Made."**

In view of the objections to the drawings as expressed in section 4 on pages 2-3 of the Office Action, provided herewith are new Figures 12 and 13 which show the features identified by the Examiner, and do not introduce new matter.

With regard to the Examiner's 35 U.S.C. 112, second paragraph, rejection, please note that claims 1-20 have been replaced by new claims 21-45. New claims 21-45 have been drafted taking into account the 35 U.S.C. 112, second paragraph, issues raised by the Examiner, are believed to be free of these issues, and are otherwise believed to be in compliance with 35 U.S.C. 112, second paragraph.

The indication that claims 6, 9, 13, and 16-18 contain allowable subject matter is greatly appreciated; however, these claims have not been rewritten in independent form because for reasons to follow it is believed that each of independent claims 21 and 32 are allowable over the references cited by the Examiner.

The instant invention pertains to a method for determining a type and approximate shape of an occurrence, i.e. a particle or defect, associated with a semiconductor wafer. Determination of the type and approximate shape is based on Applicants' finding that scattering or reflecting of light exhibits specific features with regard to types and shapes of defects or particles in or on a semiconductor wafer. With the present invention it is possible to distinguish between concave shapes having different radii of curvature, between convex shapes having different radii of curvature, or between a concave shape

defect
Fossey

and a convex shape having different radii of curvature. Claims 21 and 32 are believed to be representative of the invention.

The Examiner rejected claims 1-5, 7, 8, 10-12, 14, 15, 19 and 20 under 35 U.S.C. 102(b) as being anticipated by Fossey et al. This rejection is respectfully traversed and Fossey et al. is not applicable with regard to the newly added claims for the following reasons.

Claim 21 recites a method for inspecting a semiconductor wafer surface, which method comprises scanning a semiconductor wafer with a laser beam, detecting at least one of scattered and reflected light from a surface of the semiconductor wafer by multiple light optics, and

determining a type and approximate shape of an occurrence associated with said semiconductor wafer based on a ratio of light intensities from said multiple light optics.

Similarly, claim 32 recites a method for inspecting a semiconductor wafer surface, which method comprises scanning a semiconductor wafer with a laser beam, detecting at least one of scattered and reflected light from a surface of the semiconductor wafer by multiple light optics, and

from a difference in standard particle conversion sizes of a light point defect based on a ratio of light intensities from said multiple light optics, calculating one of

(i) a difference between a horizontal length and a vertical height of a light point defect present on a surface of said semiconductor wafer, and

(ii) a difference between two orthogonal horizontal lengths of a light point defect present on a surface of said semiconductor wafer; and

determining a type and approximate shape of an occurrence associated with said semiconductor wafer.

Such methods are not disclosed or suggested by Fossey et al.

In this regard, Fossey et al. discloses a surface inspection system and method for distinguishing between pits and particles on a surface of a workpiece. However, Fossey et al. is completely silent with regard to "determining an approximate shape" of these pits and particles.

Accordingly, because Fossey et al. is not concerned with determining shapes of pits and particles, as is the instant invention, the instant invention is completely different than that of Fossey et al. This difference is clearly established in each of the independent claims by reciting "determining...an approximate shape of an occurrence". Thus, claims 21 and 32 are not anticipated by or rendered obvious over Fossey et al.

Furthermore, with regard to claim 32, Fossey et al. does not disclose or suggest calculating either of a difference between a horizontal length and a vertical height of a light point defect, or a difference between two orthogonal horizontal lengths of a light point defect, as recited in this claim. Accordingly, for this additional reason claim 32 is not anticipated by or rendered obvious over Fossey et al.

The remaining references cited by the Examiner do not resolve the above deficiencies of Fossey et al. Specifically, Isozaki pertains to obtaining the position ("coordinate position") of foreign matter present on a semiconductor wafer, and Yamazaki et al. pertains to a method for performing a sensitivity correction according to reflectivity corresponding to a surface material of a semiconductor substrate so as to correct a size of detected foreign matter. Neither Isozaki nor Yamazaki is concerned with determining a shape of a defect or particle associated with a semiconductor substrate.

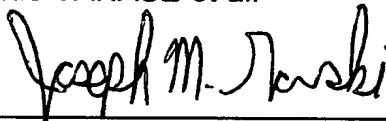
Accordingly, because none of references cited by the Examiner pertain to determining a shape of an occurrence, i.e. a defect or a particle, associated with a semiconductor wafer, any possible combination of these references would not result in the invention as recited in claims 21 and 32. Thus, claims 21-45 are allowable over the references cited by the Examiner, either taken alone or in combination.

In view of the above amendments and remarks, it is respectfully submitted that the present application is in condition for allowance and an early Notice of Allowance is earnestly solicited.

If after reviewing this Amendment, the Examiner believes that any issues remain which must be resolved before the application can be passed to issue, the Examiner is invited to contact the Applicants' undersigned representative by telephone to resolve such issues.

Respectfully submitted,

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DESCRIPTION

METHOD FOR INSPECTING SEMICONDUCTOR WAFER SURFACE

TECHNICAL FIELD

Technical Field

The present invention relates to a method for inspecting a semiconductor wafer surface and, more particularly, to a method for inspecting a semiconductor wafer surface for dividing, to detect according to the types of defects present on and near a semiconductor wafer surface, particles adherent to the semiconductor wafer surface, ^{occurrences of the semiconductor wafer} ~~thereon~~ and the like (hereinafter referred to as defects etc., including those), which affect the electrical properties such as dielectric breakdown strength of LSIs and the like being manufactured using semiconductor wafers, so as to evaluate the semiconductor wafer quality.

BACKGROUND ART

Background Art

Hitherto, extraneous substances such as particles adherent onto a semiconductor wafer, and crystal defects on and near the surface thereof or surface flaws, scratches, shallow pits and the like (hereinafter referred to as surface flaws etc., including those) have been known as light point defects (LPDs) to be detected using a semiconductor wafer surface inspection apparatus. The extraneous substances among them are observed in the shape of a convex on the semiconductor wafer surface. The crystal defects etc. are observed mainly as a quadrangular-pyramidal pit or projection [(100) wafer], or a triangular or hexagonal pit or projection [(111) wafer] on a mirror-finished wafer surface, while they are observed mainly in the shape of a square or a square partly concave or convex [(100) wafer], or in the shape of a triangle or a triangle partly concave or convex [(111) wafer] on an epitaxial wafer surface.

From the viewpoint of the evaluation of semiconductor wafer quality, it is desirable that the extraneous substances, crystal defects and surface flaws etc. should be strictly divided according to their types to be detected. However, in a conventional method for inspecting a semiconductor wafer surface, a wafer is scanned with a laser beam, a scattered light having a prescribed angle, being reflected from the wafer surface, is detected, and the result is compared with the measurement results of standard particles having prescribed grain sizes previously obtained, whereby the number of LPDs of every size including all of the extraneous substances and crystal defects is obtained.

In order to determine the types of extraneous substances and crystal defects etc. or surface flaws etc. (hereinafter referred to as defects etc., including those) in the above

method, ^a the possibility of separation by ~~the~~ unevenness recognition based on ^a the premise that grown-in defects are pit-shaped while particles are convex, for example, in ~~the~~ separation of particles and grown-in defects (COPs) in a mirror-finished wafer was reported. However, since the unevenness recognition is actually imperfect, it has been evident that it is difficult to separate particles from grown-in defects (COPs). In addition, it has been evident that all of ~~the~~ grown-in defects are not concave.

There are many types of crystal defects in an epitaxial wafer such as stacking faults (SFs), mounds, and dislocations (hereinafter referred to as epi defects), and some of the epi defects have concave shapes, some have convex shapes, and others have both concave and convex shapes. Therefore, since ~~the~~ separation probability in ~~the~~ method wherein ~~the~~ separation is conducted depending on ~~the~~ concave and convex shapes is low, and all of the epi defects are not concave, it has been physically impossible to separate the epi defects from particles; moreover, to determine ^{associated with} the types of the defects.

~~The~~ Determination of the types of the defects etc. is possible using an atomic force microscope (AFM) or a scanning electron microscope on a research level. However, in order to observe ^{these occurrences} ~~the defects etc.~~ using these microscopes, ~~the~~ coordinate positions where ^{the occurrences} ~~the defects etc.~~ exist must be detected first on a wafer surface having an enormously large area compared with ^{occurrences} ~~the defects etc.~~. The detecting activity is very ^{difficult} ~~hard~~, and then, ~~the~~ points where ^{occurrences} ~~the defects etc.~~ exist must be brought into focus of the AFM or the like. These activities cost vast labor and time, and furthermore, there is a possibility that ~~the~~ quality of ^a the product might be lowered, though they are not destructive inspection. As a result, it has been actually impossible to conduct ~~the~~ inspection using a microscope of this type on every product. Therefore, a visual distinction method ^{performed} by an inspector (a method wherein a high-intensity spotlight is irradiated in a darkroom and scatterers are detected by a visual check) has been actually adopted.

^{An occurrence} ~~The~~ defect size measured using only one light optic of a laser surface inspection apparatus is a standard particle conversion size, which may be very different from an actual size depending on ^{the occurrences} ~~the shapes of the defects etc.~~. Accordingly, there is a problem ^{with regard to} ~~left from the viewpoint of reliability in the distinction of the types of the defects etc.~~ based on ^a ~~the defect size~~. Not only does the method, wherein particles and defects are separated by judging whether ^{are} ~~the shapes~~ are concave or convex, have a low reliability, but also it cannot be applied at all to ~~the~~ wafers wherein convex defects exist. In the visual distinction method ^{performed} by an inspector, ~~the~~ distinction capacity greatly depends on the inspector's competence for the task, which is not stable, and it is difficult to respond to higher-level requirements in a future wafer inspection. Furthermore, as wafers have

larger diameters, the possibility that defects ^{occurrences} escape ^{the inspector's} attention becomes larger. In the visual distinction method ^{performed} by an inspector, the ability of the inspector must be estimated first, leading to increases in the ^{of steps} step number and cost.

SUMMARY OF THE INVENTION Disclosure of Invention

The present invention was developed in order to solve the above problems, and it is an object to provide a method for inspecting a semiconductor wafer surface, wherein particles adherent to a semiconductor wafer surface and, for example, surface flaws ~~etc~~ in a mirror-finished wafer which exist near the semiconductor wafer surface, or grown-in defects ~~etc~~ in the bulk near the surface can be separated to be detected, or adherent particles and defects ~~etc~~ such as SFs, mounds, and dislocations in an epitaxial wafer can be accurately divided according to the types ^{at a low cost} without being influenced by the inspector's ability ^{an} at a low cost.

In order to achieve the above object, ^{first} a method for inspecting a semiconductor wafer surface ~~is~~ according to the present invention is characterized by a wafer being scanned with a laser beam, a scattered or reflected light from the wafer surface being detected by multiple light optics having different detecting angles to an incident light, ^{relative} and the defect being classified into some characteristics based on the ratio of the detected light intensities from the multiple light optics, ^{on occurrence} respectively.

In the above method for inspecting a semiconductor wafer surface ~~is~~ since a wafer is scanned with a laser beam, a scattered or reflected light from the wafer surface is detected by multiple light optics having different detecting angles to an incident light, ^{relative} and the defect ^{occurrence} is classified into some characteristics based on the ratio of the detected light intensities from the multiple light optics, ^{the method} it can be utilized that there is a wide difference in the detected defect sizes between a low-angle light optic and a high-angle light optic depending on the types of the defects ^{occurrences} etc. Therefore, it becomes possible to quite accurately determine the types of the defects ^{occurrences} etc. Since the determination is not conducted by an inspector, the inspection can be automated. Without depending on the inspector's ability, ^{the inspection} it can be stable and it is possible to deal with higher-level requirements in a future wafer inspection and wafers having larger diameters. Moreover, it is unnecessary to estimate the inspector beforehand, leading to substantial reductions in the inspection-step number and cost ^{on inspection steps}.

^{second} A method for inspecting a semiconductor wafer surface ~~is~~ according to the present invention is characterized by a wafer being scanned with a laser beam, a scattered or reflected light from the wafer surface being detected by multiple light optics having different detecting angles to an incident light, ^{relative} a difference between a horizontal ^{respectively}

on claim 29

length and a vertical height or between a horizontal length and a horizontal length crossing at right angles of an LPD (Light Point Defect) present on the wafer surface, being calculated from a difference in the standard particle conversion sizes based on the ratio of the detected light intensities from the multiple light optics, and the forms and types of defects etc. present on the wafer surface being determined. *(i.e. orthogonal dimensions)* *(i.e. shapes)* *occurrences* *are* *second*

In the above method for inspecting a semiconductor wafer surface, since a wafer is scanned with a laser beam, a scattered or reflected light from the wafer surface is detected by multiple light optics having different detecting angles to an incident light, a difference between a horizontal length and a vertical height or between a horizontal length and a horizontal length crossing at right angles of a LPD (Light Point Defect) present on and near the wafer surface is calculated from a difference in the standard particle conversion sizes based on the ratio of the detected light intensities from the multiple light optics, and the forms and types of defects etc. present on the wafer surface are determined, it is possible to distinctly separate the defects etc. from extraneous substances. Furthermore, it becomes possible to quite accurately determine the types of the defects etc. Since the determination is not conducted by an inspector, the inspection can be automated. Without depending on the inspector's ability, it can be stable and it is possible to deal with higher-level requirements in a future wafer inspection and wafers having larger diameters. Moreover, it is unnecessary to estimate the inspector beforehand, leading to substantial reductions in the inspection step number and cost. *(relative)* *between two orthogonal* *(i.e. shapes)* *on* *the inspection* *also with* *of inspection* *steps* *third*

A method for inspecting a semiconductor wafer surface according to the present invention is characterized by using a laser surface inspection apparatus, comprising at least two light optics to one incidence, as a laser surface inspection apparatus in the method for inspecting a semiconductor wafer surface (1) or (2). *first or second*

When at least two light optics, a low-angle light optic and a high-angle light optic, to an incident light are included as a light-detecting system of the laser surface inspection apparatus, the above method for inspecting a semiconductor wafer surface (1) or (2) can be performed. By using the laser surface inspection apparatus comprising two light optics to one incidence as a laser surface inspection apparatus, the inspection cost can be held down. *relative* *first and second* *relative*

A method for inspecting a semiconductor wafer surface according to the present invention is characterized by the semiconductor wafer being an epitaxial semiconductor wafer in any of the methods for inspecting a semiconductor wafer surface (1)-(3). *fourth* *first through third*

By the method for inspecting a semiconductor wafer surface according to the

present invention, it is possible to accurately determine the types of defects etc. present on the wafer surface. Therefore, they can be applied even to an epitaxial semiconductor wafer which has many types of defects etc. and has a small number of defects.

A method for inspecting a semiconductor wafer surface according to the present invention is characterized by determining the forms and types of defects etc. according to a combination of A, B and a numerical value given by A/B, where the detected light intensity of a LPD (Light Point Defect) detected in a high-angle light optic, or the standard particle conversion size thereof, is A, while the detected light intensity of the LPD detected in a low-angle light optic, or the standard particle conversion size thereof, is B, in any of the methods for inspecting a semiconductor wafer surface (1)-(4).

Using the above method for inspecting a semiconductor wafer surface, particles adherent to a semiconductor wafer surface, or defects etc. such as SFs, mounds, and dislocations present near the semiconductor wafer surface can be accurately classified, so that the semiconductor wafer quality can be accurately evaluated.

A method for inspecting a semiconductor wafer surface according to the present invention is characterized by determining the forms and types of defects etc. based on Table 1, where the standard particle conversion size of a LPD (Light Point Defect) detected in a high-angle light optic is A, while the standard particle conversion size of the LPD detected in a low-angle light optic is B, in any of the methods for inspecting a semiconductor wafer surface (1)-(4).

Table 1

Relations between A and B or ranges	Actual forms types
$A \geq B \times 1.13$	Stacking Fault
$A < B \times 1.13$	Non-epi-layer originated extraneous substance (adherent particle)
$B < 90 \text{ nm}$ and $A > 107 \text{ nm}$	Micro-crystallographic-defect (hillock, shadow, dislocation)
$B > 160 \text{ nm}$ and $A < 107 \text{ nm}$	Abnormal growth (large-pit, projection)
Others	Abnormal product

Using the above method for inspecting a semiconductor wafer surface, particles adherent to a semiconductor wafer surface, or defects etc. such as SFs, mounds, and dislocations present near the semiconductor wafer surface can be accurately classified, so that the semiconductor wafer quality can be accurately evaluated.

A method for inspecting a semiconductor wafer surface according to the

present invention is characterized by the semiconductor wafer being a mirror-finished semiconductor wafer in any of the ^{first through third} methods for inspecting a semiconductor wafer surface ⁽¹⁾⁻⁽³⁾.

By the ^{first through third} methods for inspecting a semiconductor wafer surface according to the present invention, ^{occurrences} defects ~~etc.~~ present on the wafer surface, and surface flaws ~~etc.~~ and grown-in defects in ~~the~~ bulk near the surface can be accurately separated. Therefore, ^{these} ^{methods} they can be applied even to a mirror-polished semiconductor wafer.

A ^{first through third} method for inspecting a semiconductor wafer surface ⁽⁴⁾ according to the present invention is characterized by determining the forms ^(i.e. shapes) and types of ^{occurrences} defects ~~etc.~~ according to a combination of A, B and a numerical value given by A/B, where the detected light intensity of ^{an} LPD (Light Point Defect) detected ^{from} in a high-angle light optic, or the standard particle conversion size thereof, is A, while the detected light intensity of the LPD detected ^{from} in a low-angle light optic, or the standard particle conversion size thereof is B, in the method for inspecting a semiconductor wafer surface ⁽⁵⁾.

Using the above ^{first through third} method for inspecting a semiconductor wafer surface ⁽⁶⁾, particles adherent to a semiconductor wafer surface or COPs, and surface flaws ~~etc.~~ and grown-in defects ~~etc.~~ present in ~~the~~ bulk near the semiconductor wafer surface can be accurately classified, so that the semiconductor wafer quality can be accurately evaluated.

A ^{ninth} method for inspecting a semiconductor wafer surface ⁽⁹⁾ according to the present invention is characterized by determining the forms ^(i.e. shapes) and types of ^{occurrences} defects ~~etc.~~ based on Table 2, where the standard particle conversion size of ^{an} LPD (Light Point Defect) detected ^{from} in a high-angle light optic is A, while the standard particle conversion size of the LPD detected ^{from} in a low-angle light optic is B, in any of the ^{first through third and seventh} methods for inspecting a semiconductor wafer surface ^{(1)-(3) and (7)}.

Table 2

Relations between A and B or ranges	Actual forms types
$A \geq B \times 1.13$ or $B < 90 \text{ nm}$ and $A > 107 \text{ nm}$	Scratch, flaw, and shallow pit
$A < B \times 1.13$	Adherent particle or COP
$B \geq 85 \text{ nm}$ and $A < 107 \text{ nm}$	Grown-in defect in bulk near surface

Using the above ^{ninth} method for inspecting a semiconductor wafer surface ⁽¹⁰⁾, particles adherent to a semiconductor wafer surface or COPs, and surface flaws ~~etc.~~ and grown-in defects ~~etc.~~ present in ~~the~~ bulk near the semiconductor wafer surface can be

accurately classified, so that ~~the~~ semiconductor wafer quality can be accurately evaluated.

BRIEF DESCRIPTION OF THE DRAWINGS

Brief Description of Drawings

Fig. 1 is a diagram showing ~~the~~ results of classification of ~~the~~ actual forms of LPDs detected in ~~an~~ ^{a first} embodiment ~~1~~, according to the present invention after confirmed using an AFM;

Fig. 2 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 3 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 4 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 5 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 6 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 7 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 8 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 9 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~1~~, which were confirmed using the AFM;

Fig. 10 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~2~~, which were confirmed using the AFM; and

Fig. 11 is a microphotograph showing an example of ~~the~~ actual forms of ~~the~~ LPDs detected in the embodiment ~~2~~, which were confirmed using the AFM.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Best Mode for Carrying Out the Invention

The preferred embodiments of ~~the~~ method for inspecting a semiconductor wafer surface according to the present invention are described below by reference to the Figures of the Drawings.

In a method for inspecting a semiconductor wafer surface according to an embodiment, using, for example, a laser surface inspection apparatus having two light optics, ^{stationary} to one incidence, LPDs are detected ^{from} in the two light optics, ^{i.e. a} low-angle and ^{one} high-angle ones, respectively. A list of the coordinates of the LPDs obtained ^{from} in each

① Fig. 12 schematically depicts performance of a method of the invention; and
Fig. 13 depicts horizontal and vertical dimensions of occurrences in a semiconductor wafer.

light optic, detected light intensity or standard particle conversion size data thereof, and (high-angle detected light intensity or standard particle conversion size / low-angle detected light intensity or standard particle conversion size) is prepared.

The LPDs detected only ^{from} in the high-angle light optic, the LPDs detected only ^{from} in the low-angle light optic, and the LPDs having various values of (high-angle detected light intensity or standard particle conversion size / low-angle detected light intensity or standard particle conversion size) are selected and ~~the~~ actual forms thereof are actually observed using an AFM or the like.

On the basis of the actual forms of the LPDs observed using the AFM or the like, ^{occurrences of the semiconductor wafer} the characteristics of defects etc. are grasped according to their types from ^{from} the comparison between the detected light intensities or standard particle conversion sizes detected in each of the low-angle and high-angle light optics. As a result, for example, the relationships between the standard particle conversion sizes detected ^{from} in each of the low-angle and high-angle light optics and the types of defects in an epitaxial wafer and in a mirror-finished wafer could be classified and arranged as shown in Tables 1 and 2, respectively.

Table 1

Relations between A and B or ranges	Actual forms- types
$A \geq B \times 1.13$	Stacking Fault
$A < B \times 1.13$	Non-epi-layer originated extraneous substance (adherent particle)
$B < 90 \text{ nm}$ and $A > 107 \text{ nm}$	Micro-crystallographic-defect (hillock, shadow, dislocation)
$B > 160 \text{ nm}$ and $A < 107 \text{ nm}$	Abnormal growth (large-pit, projection)
Others	Abnormal product

Table 2

Relations between A and B or ranges	Actual forms- types
$A \geq B \times 1.13$ or $B < 90 \text{ nm}$ and $A > 107 \text{ nm}$	Scratch, flaw, and shallow pit
$A < B \times 1.13$	Adherent particle or COP
$B \geq 85 \text{ nm}$ and $A < 107 \text{ nm}$	Grown-in defect in bulk near surface

Here, A represents the standard particle conversion size of ^{an} LPD detected ^{from} in the high-angle light optic, while B represents the standard particle conversion size of ^{an} LPD detected ^{from} in the low-angle light optic.

However, ~~the~~ angles of the light optics are different depending on ^athe used laser surface inspection apparatus, and each laser surface inspection apparatus has its own minimum and maximum limits of measurement. Therefore, there is a possibility that the values of A, B, and A/B used for defect distinction might vary according to ^{the used}laser surface inspection apparatus. In addition, in the case of an epitaxial wafer, ^{the defect size}the defect size depends on ^{on}the thickness of ^{the}epitaxial film (in the case of a (100) wafer, ^{the}the SF length is about 1.4 times the epitaxial film thickness), so that there is a possibility that the values of A, B, and A/B might vary when the epitaxial film thickness varies.

By a conventional method, in the case of an epitaxial wafer, the number of LPDs of every size ^{from}in one light optic, including all of ^{the}extraneous substances and epi defects detected using a laser surface inspection apparatus, can be obtained, while in the case of a mirror-polished wafer, the number of LPDs of every size ^{from}in one light optic, including all of ^{the}extraneous substances and grown-in defects detected using a laser surface inspection apparatus, can be obtained. However, it is impossible to divide and detect ^{occurrences of the semiconductor wafer}defects, etc. according to the types as shown in Table 1 or 2.

^{An occurrence}The defect size measured using only one light optic of a laser surface inspection apparatus is a standard particle conversion size, which may be very different from an actual size depending on ^{occurrences}the shapes of the defects, etc. Accordingly, ^{with regard to}there is a problem ^{occurrences}left from the viewpoint of reliability in the distinction of the types of the defects, etc. based on the ^{occurrence}defect size. In the visual distinction method by an inspector, ^athe distinction capacity greatly depends on the inspector's competence for the task, which is not stable, and it is difficult to respond to higher-level requirements in a future wafer inspection. Furthermore, as wafers have larger diameters, ^{occurrences}the possibility that defects, etc. escape his attention becomes larger. In the visual distinction method by an inspector, ^{number of steps}the ability of the inspector must be estimated first, leading to increases in the ^{number of steps}step number and costs.

In the method for inspecting a semiconductor wafer surface according to the embodiment, on the basis of ~~the~~ coordinate data of the LPDs detected using the laser surface inspection apparatus, the LPDs detected only in the high-angle light optic, the LPDs detected only in the low-angle light optic, and the LPDs having various values of (high-angle detected light intensity or standard particle conversion size / low-angle detected light intensity or standard particle conversion size) are selected. On the basis of ~~the~~ results of the actual forms thereof actually observed using an AFM, the LPDs are classified and arranged to prepare Tables 1 and 2. Once ~~the~~ Table 1 or 2 is prepared, only ~~the~~ organization of the standard particle conversion sizes detected ^{from}in each of the low-angle and high-angle light optics, using the laser surface inspection apparatus, according to the classification shown in Table 1 or 2 is needed to divide easily and

accurately ~~the~~ extraneous substances and defects ~~etc.~~ or surface flaws ~~etc.~~ according to their types.

Since the distinction is not conducted by an inspector, the inspection can be automated, so that it can be stably conducted without depending on the inspector's ability. It is also possible to deal with higher-level requirements in a future wafer inspection, and wafers having larger diameters. Moreover, it is unnecessary to estimate the inspector beforehand, leading to substantial reductions in the inspection ^{of inspection steps} step number and cost.

In the method for inspecting a semiconductor wafer surface according to the embodiment, ^{relative} the case where the laser surface inspection apparatus having two light optics to one incidence is used ~~as a laser surface inspection apparatus is described~~, but the laser surface inspection apparatus is not ^{so} limited ~~to the laser surface inspection apparatus having two light optics to one incidence~~. In another embodiment, a laser surface inspection apparatus having two light optics ^{relative} to two incidences, or a laser surface inspection apparatus having three light optics ^{relative} to one incidence, can be used.

When the laser surface inspection apparatus has at least two light optics having different detecting angles ^{relative} to an incident light, as a light-detecting system thereof, it is possible to conduct the method for inspecting a semiconductor wafer surface according to the present invention. And, using the laser surface inspection apparatus having two light optics ^{relative} to one incidence ~~as a laser surface inspection apparatus~~, the inspection cost ^{relative} can be held down.

By the method for inspecting a semiconductor wafer surface according to the embodiment, ^{occurrences} the types of defects ~~etc.~~ present on a wafer surface can be accurately determined, so that the method can be applied not only to the detection of surface flaws of a mirror-polished semiconductor wafer sliced off from a single crystal, but also to an epitaxial semiconductor wafer having many types of defects ^{occurrences} ~~etc.~~ and a small number of defects. ^{occurrences} The quality evaluation of both the epitaxial semiconductor wafer having many types of defects ^{occurrences} ~~etc.~~ and the mirror-polished wafer can be accurately conducted.

EXAMPLES AND COMPARATIVE EXAMPLES

Examples and Comparative Examples

Examples of the method for inspecting a semiconductor wafer surface according to the present invention are described below.

Example 1

Used laser surface inspection apparatus: SP-1 (produced by TENCOR)

Two light optics ^{relative} to one incidence

Used sample: 200 mm epitaxial silicon wafer

Wafer crystal plane (100)

Epitaxial film thickness $6 \mu\text{m}$

The LPDs of the sample epitaxial silicon wafer were detected using the above laser surface inspection apparatus.

The data of the coordinates and standard particle conversion sizes of the LPDs obtained in each of the two light optics were organized, and the actual forms of the LPDs were presumed based on the classification shown in Table 1 and Fig. 1. Part of the results of the data processing are shown in Table 3.

Table 3

Detection results by laser surface inspection apparatus			A F M	Results
Low-angle light-receiving channel (nm)	High-angle light-receiving channel (nm)	Presumption		
Below detection limit	115	Micro-crystallographic-defect (dislocation, shadow)	Length $10 \mu\text{m}$ · height 3 nm (Fig. 2)	○
Below detection limit	160	Micro-crystallographic-defect (hillock)	Diameter $1 \mu\text{m}$ × height 20 nm (Fig. 3)	○
95	127	S F	S F (Fig.4)	○
108	136	S F	S F (Fig.5)	○
106	136	S F	S F	○
107	135	S F	S F	○
107	134	S F	S F	○
149	150	Adherent particle	Adherent particle (Fig. 6)	○
104	111	Adherent particle	Adherent particle	○
90	118	S F	S F	○
Above detection limit	Above detection limit	Mound	Mound · abnormal growth(Fig. 7)	○

Then, on the basis of the coordinate data of the obtained LPDs, the actual forms of the LPDs detected using the laser surface inspection apparatus were actually confirmed using an AFM, and whether the classification based on Table 1 and Fig. 1 was correct or wrong was judged. The results are also shown together in Table 3.

In Figs. 2-9, typical examples of microphotographs of the actual forms of the LPDs confirmed using the AFM are shown. In Table 3, in order to clarify to which the LPDs shown in Figs. 2-7 correspond, the Figure numbers are included in the AFM

column. The LPD shown in Fig. 8 is an example of ^{an} LPD~~s~~ which should be classified as the division ($B > 160$ nm and $A < 107$ nm) in Table 1, while the LPD shown in Fig. 9 is an example of ^{an} LPD~~s~~ which should be classified as the division (Others) in Table 1.

In the method according to the Example, the LPDs could be accurately classified according to their forms ^(i.e. shapes) with a probability of at least 90 % ~~or more~~ by a simple method using a laser surface inspection apparatus.

Comparative Example 1

Used laser surface inspection apparatus: SFS6220 (produced by TENCOR)
One light ^{relative} optic to one incidence

Used sample: 200 mm epitaxial silicon wafer

Wafer crystal plane (100)

Epitaxial film thickness $2.1 \mu\text{m}$

~~The~~ LPDs of the sample epitaxial silicon wafer were detected using the above laser surface inspection apparatus.

~~As Comparative Example, the~~ Classification based on ~~the~~ standard particle conversion size data of the LPDs using the laser surface inspection apparatus, and ~~the~~ classification by ~~the~~ method wherein a high-intensity spotlight is irradiated in a darkroom and scatterers are detected by a visual check, were conducted. ~~The~~ actual forms of ~~the~~ detected LPDs were confirmed using an AFM, and whether the classification was correct or wrong was judged. The results are shown in Table 4.

Table 4

Laser surface inspection apparatus	Visual check	A F M
$0.1 \mu\text{m} > 10$ LPDs	None	10 SFs ($3 \mu\text{m}$ -side square, L-shaped, U-shaped and linear)
$0.1 - 0.3 \mu\text{m}$ 5 LPDs	3 SFs	2 SFs ($3 \mu\text{m}$ -side square), 1 pit of diameters $3.0 \mu\text{m} \times 0.2 \mu\text{m}$, 1 abnormal crystal growth, and 1 adherent particle
$0.3 \mu\text{m} < 3$ LPDs	3 extraneous substances	2 non-epi-layer originated extraneous substances and 1 mound

As is obvious from the results shown in Table 4, in the classification by a visual check, ^athe detecting rate of LDPs as a precondition reached only 30 % (6 LPDs / 18 LPDs), which made clear that there was a problem before classification. And, among the detected LPDs, only 50 % or so could be divided correctly. Thus, it was confirmed ~~that~~, in the visual distinction by an inspector, ^{that} the distinction was unstable, that it was difficult

to deal with higher-level requirements in a future wafer inspection, and that the probability that ~~the~~ defects ~~etc.~~ ^{the inspectors} may escape ~~his~~ attention might become larger as wafers have larger diameters.

Example 2

Used laser surface inspection apparatus: SP-1 (produced by TENCOR)

Two light optics to one incidence

Used sample: 200 mm mirror-polished CZ silicon wafer

Wafer crystal plane (100)

The LPDs of the sample mirror-polished CZ silicon wafer were detected using the above laser surface inspection apparatus.

The ~~Data~~ of the coordinates and standard particle conversion sizes of the LPDs obtained in each of the two light optics were organized, and the actual forms of the LPDs were presumed based on the classification shown in Table 2. ~~Part of~~ ^{A portion of} the results of the data processing are shown in Table 5.

Table 5

Detection results by laser surface inspection apparatus			AFM	Results
Low-angle light-receiving channel (nm)	High-angle light-receiving channel (nm)	Presumption		
Below detection limit	112	Scratch or s-pit	Scratch of length 3 μ m (Fig. 10)	○
Below detection limit	115	Scratch or s-pit	Scratch	○
98	142	Scratch or s-pit	s-pit (Fig. 11)	○
110	149	Scratch or s-pit	s-pit	○
86	132	Scratch or s-pit	Scratch	○
91	Below detection limit	Grown-in defect in bulk	No unevenness observed	○
88	Below detection limit	Grown-in defect in bulk	No unevenness observed	○
132	133	Adherent particle	Adherent particle	○
104	109	Adherent particle	Adherent particle	○

Then, on the basis of the coordinate data of the obtained LPDs, the actual forms of the LPDs detected using the laser surface inspection apparatus were actually

confirmed using an AFM, and whether the classification based on Table 2 was correct or wrong was judged. The results are also shown together in Table 5.

In Figs. 10 and 11, typical examples of microphotographs of the actual forms of the LPDs confirmed using the AFM are shown. In Table 5, in order to clarify to which the LPDs shown in Figs. 10 and 11 ~~correspond~~^{correspondence}, the Figure numbers are included in the AFM column. In the method according to the Example, the LPDs could be accurately classified according to their forms^(i.e. shapes) with a probability of at least 90 % ~~or more~~ by a simple method using a laser surface inspection apparatus.

INDUSTRIAL APPLICABILITY

The instant invention

~~This~~ can be utilized for dividing to detect according to the types of defects present on and near a semiconductor wafer surface, adherent particles and the like, which affect the electrical properties such as dielectric breakdown strength of LSIs and the like manufactured using semiconductor wafers, so as to evaluate the semiconductor wafer quality.

ABSTRACT OF THE DISCLOSURE

~~The present invention was achieved in order to provide an inspection method~~
whereby ^{at a low cost} particles adherent to a semiconductor wafer surface, and defects ~~etc.~~ such as SFs, mounds, and dislocations present near the semiconductor wafer surface can be accurately divided according to their types ^{at a low cost} without being influenced by ^{an} the inspector's ability. ~~at a low cost, wherein~~ The wafer is scanned with a laser beam, ~~a~~ scattered or reflected light from the wafer surface is detected ^{from} in multiple light optics having different detecting angles ^{respectively}, and the forms and types of the defects ~~etc.~~ ^{occurrences} present on the wafer surface are determined based on the ratio of the detected light intensities from the multiple light optics.